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GB 2225908 A GB 1284964 A EP 0360933 A1
EP 0186873 A2 US 4912589 A US 4323942 A

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(54) Overvoltage protector

(57) The purpose is to provide a protection circuit which passes all normal operating voltages on ring and tip telephone wires and limits the peak voltage increase during a lightning impulse to a level comparable to the battery voltage. For example, normal operating voltages of 200 V peak would be passed, and under lightning impulse conditions the voltage increase would be limited to about 90 V.

The circuit has a two terminal voltage responsive thyristor PA1 in series with a gate triggered thyristor PB. A lightning impulse causes a capacitor C to pass sufficient current to trigger thyristor PB, whereas under AC disturbing voltage conditions the thyristor PB is triggered by a symmetrical avalanche diode D. The switching speed of thyristor PB is made very fast by its having a low holding current (eg. 10 mA). Thyristor PA1 has a higher holding current (eg. 150 mA) and so turns off before thyristor PB after an overvoltage. A resistor may be connected between the gate and MT1 (ground) terminals f thyristor PB to reduce its variation of triggering current with temperature.

Parts or all of the circuit may be integrated (Fig. 6); circuits for the ring and tip wires may be integrated on a single chip.

Fig.3.

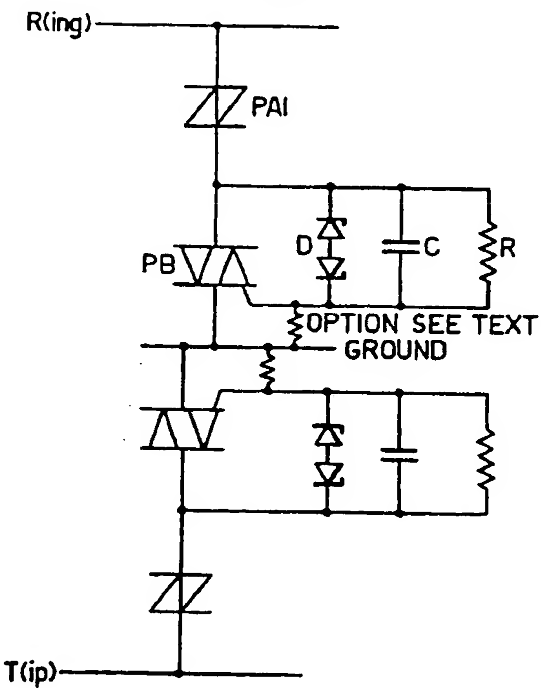

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Fig.1.

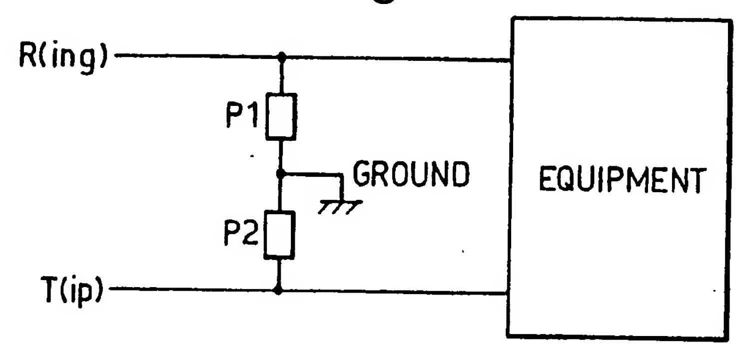

R(ing)
P1
GROUND
P2
T(ip)
EQUIPMENT

Fig.2.

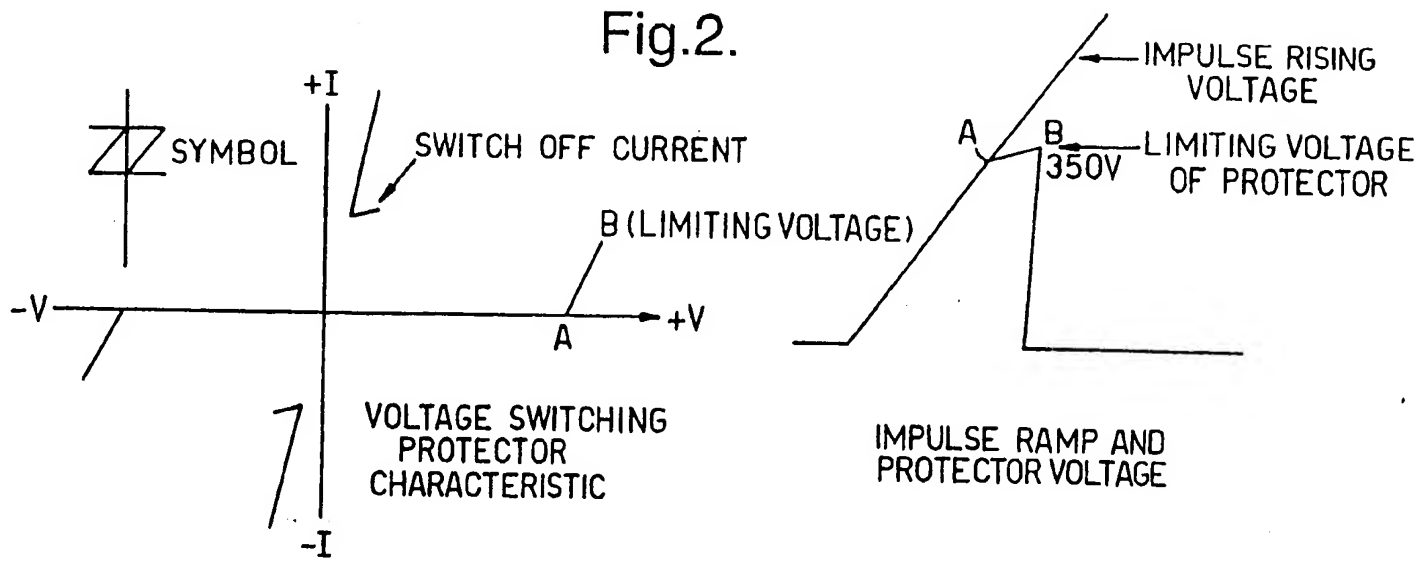

SYMBOL
+I
SWITCH OFF CURRENT
B (LIMITING VOLTAGE)
-V
A
+V
-I
VOLTAGE SWITCHING
PROTECTOR
CHARACTERISTIC
IMPULSE RISING
VOLTAGE
A
B
350V
LIMITING VOLTAGE
OF PROTECTOR
IMPULSE RAMP AND
PROTECTOR VOLTAGE

Fig.3.

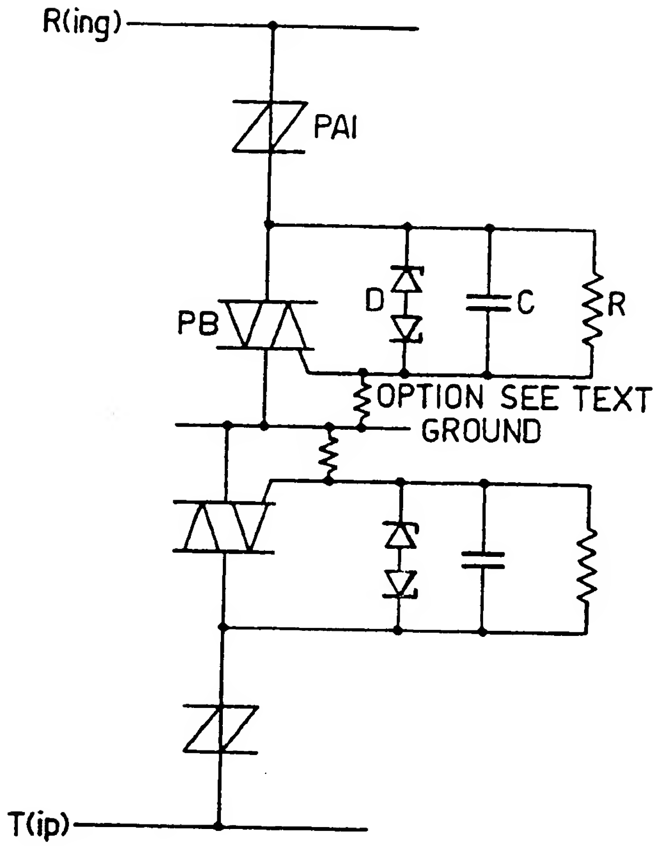
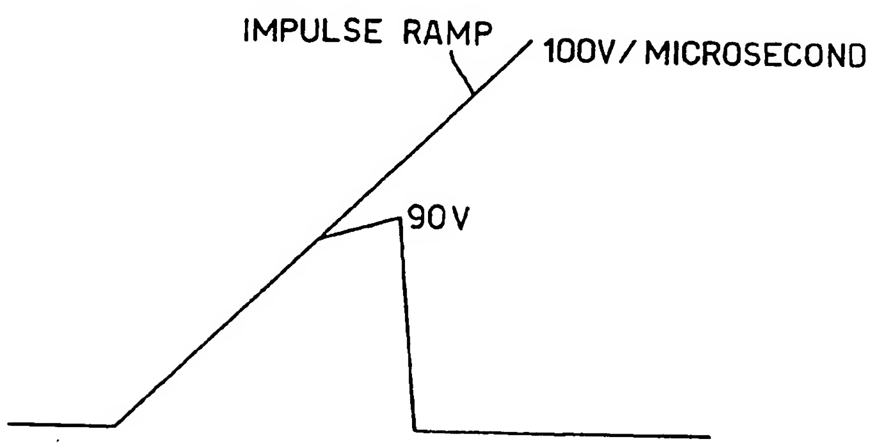

R(ing)
PAI
D
C
R
PB
OPTION SEE TEXT
GROUND
T(ip)

Fig.4.


IMPULSE RAMP
100V/ MICROSECOND
90V

2298533

IMPROVED OVERVOLTAGE PROTECTOR

In the telephone system the principal method of connection between the exchange and the subscriber equipment is by a two wire telephone line. It is practice in the USA for the wires to be called R(ing) and T(ip), while in other areas they are referred to as A and B.

In normal operation the R and T wires will be at different potentials wth respect to ground. For a given system practice there will be maximum values that these voltages can assume in normal operation. The maximum positive and negative voltages that the R and T wires can reach are not necessarily the same. Also the voltage differential between the wires may not be as large as the sum of maximum positive and negative excursions of the two line wires with respect to ground.

Telephone equipment with components connected from any of the wires to ground and between the wires must have adequate voltage ratings to withstand the voltage potentials which occur in normal operation. Typically, a battery voltage of about 50 V will be applied to the line and, during ringing, an additional ac voltage of 100 Vrms (141 V peak) will be applied. Under these conditions a peak voltage of 50 + 142 = 192 V will occur. After allowing for tolerancing, the equipment might be designed for a maximum voltage of 200 V in normal operation.

Under disturbing (abnormal) voltage conditions, caused by lightning, power line contact and induction from electrical machines, the above components must be protected against failure from these dangerous overvoltages which can occur on the line wires.

Figure 1 shows an overvoltage protection arrangement which uses two voltage limiting devices, P1 and P 2, connected from each line wire to ground. From the above example, these protectors must not limit the voltage from reaching 200 V, otherwise the normal operation of the telephone system would be impaired. The voltage limiting level of the protectors depends on the protection technology and the type of disturbing voltage that occurs. Typically, the limiting voltage of the protector passing 200 V might be 300 V under ac conditions and 350 V for fast rising/high current lightning impulse conditions.

To minimise the time for which the high voltage exists, voltage switching (crowbar) protectors are used. The characteristic and voltage limiting performance of a voltage switching protector is shown in Figure 2. When the impulse finishes the protector, in its low voltage state, will still have the wire current from the exchange battery flowing in it. It is most important that the protector switches off at this current, otherwise the line would remain shorted to ground preventing normal operation. In thyristor voltage switching protectors, this switch off current is controlled by shorting dots (S W Byatt & R A Rodrigues: British Patent Application GB 2113 907 A, "Reverse-Breakdown PN Junction devices", published August 1983). Unfortunately, the presence of these dots slows the protector switching and this contributes to the limiting voltage increase from ac to impulse conditions (300 V to 350 V). Typically the line dc is about 50 mA, so protectors are made with minimum switch off currents of about 150 mA.

In summary, for the example quoted, equipment designed to operate up to 200 V peak requires components rated for at least 350 V. But, as the disturbing voltage conditions are not controlled, for long service life the components may need even higher voltage ratings.

According to one aspect of the present invention, there is provided an overvoltage protection circuit comprising a first protector operable between a first voltage and a second voltage to effect a first level of protection; a second protector in series with the first protector and being operable at a predetermined current to be rapidly conducting thereby providing further protection.

According to a second aspect of the present invention, there is provided telephone equipment including an overvoltage protection circuit according to any of the claims.

According to a third aspect of the present invention, there is provided a method of protecting equipment from overvoltage comprising the steps: providing a first protector operable between a first and second voltage to protect the equipment from overvoltage up to a predetermined level; providing a second protector for protecting the equipment beyond the predetermined overvoltage level; connecting the first and second protectors in series; and switching the protectors at different voltage and/or current levels to provide protection for a full range of overvoltages.

Reference will now be made, by way of example to the accompanying drawings, in which:

Figure 1 is a prior art ring and tip line wire overvoltage protector;

Figure 2 is two graphs showing the voltage switching protector characteristics and the impulse ramp and protector voltages;

Figure 3 is a circuit configuration of an overvoltage protector of the present invention;

Figure 4 is a graph showing the impulse voltage circuitry of the Figure 3 protector;

Figure 5 is an alternative protector according to the present invention; and

Figure 6a to 6d show integration options for the Figure 3 and Figure 5 circuits.

The purpose of this invention is to make a protection function which passes all the normal operating voltages and limits the peak voltage increase during a lightning impulse to a level comparable to the battery voltage. Based on the example given, normal operating voltages of 200 V peak would be passed and under lightning impulse conditions the voltage increase would be limited to about 90 V.

Figure 3 shows one realisation of this function. Each line wire would have similar protection circuits, so only the operation of one of the two circuits will be described. Protector component integration is possible in a practical realisation. Each set of line wire protectors could be integrated into a single chip or one pair of similar protectors, one from each line wire protector, could be integrated.

The circuit consists of two protectors connected in series. Protector PA is a standard thyristor protector with a working (pass) voltage of 50 V and an impulse limiting voltage of 87 V. The second protector consists of a gated bi-directional thyristor, PB, with a 150 V symmetrical avalanche diode, D, connected between the gate and MT2. In parallel with the avalanche diode, D, is a resistor, R , and a capacitor, C. The capacitor value is small, such that, during ringing, the ringing ac, Iac, through the capacitor will not be large enough to trigger the thyristor PB. If, for instance, a current of 1 mA rms will not trigger the thyristor PB; then at the full ring voltage, Vac, of 100 Vrms and a frequency, f, of 20 Hz, the maximum capacitor value would be:-

$$C < Iac/(2*PI*f*Vac) = 1E\text{-}3/(2*PI*30*100) = 50\ nF$$

Under lightning impulse conditions, when the voltage rate of rise, dv/dt, can exceed 100 V/microsecond, the capacitor will pass a current, Ip, of:

$$Ip = C*dv/dt = 50E\text{-}9*100/1E\text{-}6 = 5\ A$$

Protector PB can be made so that this level of current will trigger it into rapidly conduction. The protection sequence is shown in Figure 4. Initially the protection circuit is inactive. Most of the 100 V/microsecond ramp is developed across protector PA, as its capacitance value is much lower than capacitor C. The limiting voltage of protector PA is 87 V and when this is reached it switches applying the 100 V/microsecond to protector PB, which would switch on as a result of the 5 A capacitive current calculated earlier. Due to this action, the limiting voltage is about 90 V, a major improvement from previous 350 V. In practice, it is probable that protector PB would already be on before protector PA switches as a result of the current passed by protector PA prior to switching. The switching speed of protector PB can be made very fast by making its switch-off current low, say 10 mA.

Protector PB is in series with protector PA. The impulse causes both protectors to switch on. As the impulse current subsides, the protector PA (150 mA switch off current) will switch off before protector PB (10 mA switch off current). When protector PA switches off the wire voltage will rise to the exchange battery level and, at this voltage level, protector PA will block any current flow that would maintain protector PB in conduction. As a result protector PB has its current reduced to zero and it switches off allowing normal operation to be restored. Thus a low high switching speed thyristor can be used for protector PB without its low value of switch off current causing permanent switch on from the line dc.

Under ac disturbing voltage conditions the triggering current for protector PB is supplied by the avalanche diode D. The limiting voltage of

protector PA would be about 75 V and that of protector PB 150 V from the diode D, giving a limiting voltage of 225 V. Lightning impulses and ac transients are seen as the major cause of equipment failure. So, although this invention is comparable with conventional protection under ac distrubing voltage conditions, its improved performance under impulse conditions considerably reduce impulse damage, the biggest cause of equipment failure.

Resistor R serves to discharge capacitor, preventing charge lock up on the capacitor which would cause an offset voltage bias. Its resistance value can be high so that line leakage resistance testing could be performed, a value of 1 Mohm would give a discharge time constant of 50 ms.
The 50 nF capacitor does not cause capacitive line loading problems as it is in series with the much lower capacitance of protector PA. Typically the capacitance of protector PA will be about 100 pF.

There are many variations on this approach. The avalanche diode D could be integrated with protector PB. If a higher impulse limiting voltage could be tolerated the circuit could the reduced to Figure 5. Here, to meet the example values, PA1 and PA2 would be of 100 V pass voltage and diode D would be 100 V to give a net pass voltage of 200 V. Under impulse condition the limiting voltage to ground would be about 180 V, still an improvement on the 350 V of the conventional approach. Protectors PA1 and PA2 are available as a single component (packaged and as a single chip) and this reduces the number of component parts. It is also possible to integrate protector PB on the same chip as protectors PA1 and PA2. The temperature variation of the protector PB triggering current maybe reduced by connecting an additional resistor between the gate and MT1.

This invention provides the following advantages:

An overvoltage protection circuit which has a substantially lower impulse limiting voltage than its normal working voltage.

An overvoltage protection circuit having reduced component count due to integration of similar protector types between line wires or disimilar protectors in a line wire to ground protection function.

An overvoltage protection circuit with fast switching though the use of a protector that would normally cause dc line lock up, but is prevented in doing so by having a conventional protector in series with a working (pass) voltage greater than or equal to the battery voltage.

An overvoltage protection circuit which allows a smaller area protector as the normal shorting dot area is much reduced. This low switch off current protector that would normally cause dc line lock up, but is prevented in doing so by having a conventional protector in series with a working (pass) voltage greater than or equal to the battery voltage.

CLAIMS

1. An overvoltage protection circuit comprising a first pr tector operable between a first voltage and a second voltage to effect a first level of protection;
a second protector in series with the first protector and being operable at a predetermined current to be rapidly conducting thereby providing further protection.

2 A circuit according to claim 1, wherein the first protector switches as the second protector becomes rapidly conducting.

3. A circuit according to claim 1, wherein or claim 2, wherein both protectors are switched on by an impulse and wherein the first protector switches off first as the impulse subsides.

4. A circuit according to any preceding claim, wherein the first protector is a standard thyristor protector.

5. A circuit according to any preceding claim, wherein the second protector comprises a bidirection thyristor, a diode and a capacitor connect to form a dc line lock, which dc line lock is inhibited by the first protector except when an overvoltage of a critical value is reached.

6. A circuit according to any preceding claim, further comprising two first protectors connected in series between two lines and one second protector connected between a node between said two first protectors and ground.

7. A circuit substantially as hereinbefore described with reference to and as illustrated in Figure 3 to 6 of the accompanying drawings.

8. Telephon equipment including an overvoltage protection circuit according to any preceding claim.

9. A method of protecting equipment from overvoltage comprising the steps:
providing a first protector operable between a first and second voltage to protect the equipment from overvoltage up to a predetermined level;
providing a second protector for protecting the equipment beyond the predetermined overvoltage level;
connecting the first and second protectors in series; and
switching the protectors at different voltage and/or current levels to provide protection for a full range of overvoltages.

10. A method substantially as hereinbefore described with reference to and as illustrated in Figure 3 to 6 of the accompanying drawings.

Patents Act 1977
Examiner's report to the Comptroller under Section 17
(The Search report)

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Relevant Technical Fields (i) UK Cl (Ed.M) H2H (HAPB, HAPC) H2K (KJJ) (ii) Int Cl (Ed.5) H02H 3/02, 3/22, 9/04; H04M 1/74, 3/18 **Databases** (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii)	Application number GB 9415350.9 Search Examiner M J BILLING Date of completion of Search 11 OCTOBER 1994 Documents considered relevant following a search in respect of Claims :- 1-6, 9

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2225908 A	(TEXAS INSTRUMENTS) eg see abstract; Figure 2	1, 6, 9 at least
X	GB 1284964	(M & T) eg see Figure 12	1, 4, 9 at least
X	EP 0360933 A1	(SEMITRON) eg see page 3 lines 7-15; figures	1, 3, 4, 9 at least
X	EP 0186873 A2	(NIPPON TELEGRAPH) eg see Figures 3, 11, 13	1, 9 at least
X	US 4912589	(TII) eg see column 5 lines 8-19; Figure 3	1, 3, 9 at least
X	US 4323942	(BELL) eg see Figure 2	1, 9 at least

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).